CLAIMS:

1. A method of estimating a speed of a motor comprising:

a) determining a correlation between a current wave sensed at the motor and frequency pairs from a set of weighted frequency pairs representing the current wave;

b) fitting components of a motor control signal to a corresponding number of first orthogonal pairs in a set of weighted orthogonal pairs, the orthogonal pairs being orthogonal to the frequency pairs;

c) fitting each of the frequency pairs as the orthogonal pair subsequent to the first orthogonal pairs;

d) identifying the frequency pairs that provide a reduction in the mean squared error between the current wave and the set of weighted orthogonal pairs that satisfies a criteria; and

e) comparing desired frequencies from the identified frequency pairs with a motor speed harmonic model to determine an estimation of the speed.

2. The method according to claim 1 wherein the step of determining a correlation comprises:

calculating a zero-filled fast fourier transform of the current wave using the frequency pairs, wherein the frequency pairs correspond to frequency index bins of the zero-filled fast fourier transform.

3. The method according to claim 1 wherein the step of fitting components of the motor control signal comprises:

determining the orthogonal weights of the first orthogonal pairs based on the values of the components; and

determining the frequency weights of pairs in the set of frequency pairs corresponding to the first orthogonal pairs based on the determined orthogonal weights.

4. The method according to claim 1 wherein the step of fitting components of the motor control signal comprises:

determining if a previous motor speed is classified as low;

fitting a drive frequency component of the motor control signal as a first pair of the orthogonal pairs; and

fitting a supplemental frequency component of the motor control signal as a second pair of the orthogonal pairs if the previous motor speed is classified as low.

5. The method according to claim 4 wherein the step of determining if a previous motor speed is classified as low comprises:

classifying the previous motor speed as low if the motor speed is less than 2% rated base motor speed.

6. The method according to claim 1 wherein the step of fitting each of the frequency pairs comprises:

determining the orthogonal weight of the subsequent orthogonal pair for each of the frequency pairs based on the value of each of the frequency pairs; and

determining the frequency weight of a pair in the set of weighted frequency pairs corresponding to the subsequent pair based on the determined orthogonal weight of the subsequent orthogonal pair for each of the frequency pairs.

7. The method according to claim 1 wherein the step of identifying comprises:

determining a mean squared error between the first orthogonal pairs and the current wave;

determining reductions in the mean squared error between the orthogonal pairs and the current wave based on the addition of each of the frequency pairs as the subsequent orthogonal pair; and

determining the frequency pairs that produce a reduction that satisfies the criteria.

8. The method according to claim 7 wherein the step of determining the frequency pairs comprises:

determining the frequency pairs that produce a reduction greater than a threshold.

9. The method according to claim 8 wherein the step of determining the frequency pairs comprises:

determining the frequency pairs that produce a reduction within a threshold of the highest reduction.

10. The method according to claim 1 further comprising:

repeating steps (b) to (d) until a performance criteria is satisfied.

11. The method according to claim 10 further comprising:

repeating steps (b) to (d) until a determined number of the frequency pairs in the set of weighted frequency pairs have been fit to the orthogonal pairs.

12. The method according to claim 10 further comprising:

repeating steps (b) to (d) until the mean squared error between the current wave and the set of weighted orthogonal pairs is below a determined threshold.

13. The method according to claim 10 further comprising:

repeating steps (b) to (d) until the reduction is less than a threshold.

14. The method according to claim 1 wherein the step of comparing comprises:

removing frequencies that are harmonics of the components of the motor control signal from the identified frequency pairs to form the desired frequencies.

15. The method according to claim 1 wherein the step of fitting components of the motor control signal comprises:

determining the first orthogonal pairs based on an orthogonalization algorithm using the components of the motor control signal.

16. The method according to claim 15 wherein the step of fitting components of the motor control signal further comprises:

calculating weights of the first orthogonal pairs.

17, The method according to claim 15 wherein the orthogonalization algorithm comprises the Gram-Schmidt algorithm or the modified Gram-Schmidt algorithm.

18. The method according to claim 1 wherein the step of fitting each of the frequency pairs comprises:

determining the subsequent pair based on an orthogonalization algorithm using the components of the motor control signal.

19. The method according to claim 18 wherein the step of fitting each of the frequency pairs further comprises:

calculating a weight for the subsequent pair for each of the frequency pairs.

20. The method according to claim 18 wherein the orthogonalization algorithm comprises the Gram-Schmidt algorithm or the modified Gram-Schmidt algorithm

21. A method of estimating a speed of a motor using a current wave sensed at the motor, the method comprising:

determining a correlation between a current wave sensed at the motor and frequency pairs from a set of weighted frequency pairs representing the current wave;

fitting components of a motor control signal to a corresponding number of first orthogonal pairs in a set of weighted orthogonal pairs, the orthogonal pairs being orthogonal to the frequency pairs;

fitting each of the frequency pairs as the orthogonal pair subsequent to the first orthogonal pairs;

determining a reduction for each of the frequency pairs in a mean squared error between the current wave and the set of weighted orthogonal pairs according to a mean squared error between the current wave and the first orthogonal pairs;

determining the reductions that satisfy a criteria and the corresponding frequency pairs;

removing unwanted frequencies from the determined corresponding frequency pairs; and

comparing the remaining frequencies from the determined corresponding frequency pairs with a motor speed harmonic model to determine an estimate for the speed.

22. The method according to claim 21 wherein the step of determining a correlation comprises:

calculating a zero-filled fast fourier transform of the current wave using the frequency pairs, wherein the frequency pairs correspond to frequency index bins of the zero-filled fast fourier transform.

23. The method according to claim 21 wherein the step of fitting components of the motor control signal comprises:

determining the orthogonal weights of the first orthogonal based on the values of the components; and

determining the frequency weights of pairs in the set of frequency pairs corresponding to the first orthogonal pairs based on the determined orthogonal weights; and

wherein the step of fitting each of the frequency pairs comprises:

determining the orthogonal weight of the subsequent orthogonal pair for each of the frequency pairs based on the value of each of the frequency pairs; and

determining the frequency weight of a pair in the set of weighted frequency pairs corresponding to the subsequent pair based on the determined orthogonal weight of the subsequent orthogonal pair for each of the frequency pairs.

24. The method according to claim 21 wherein the step of fitting components of the motor control signal comprises:

determining if a previous motor speed is classified as low;

fitting a drive frequency component of the motor control signal as a first pair of the orthogonal pairs; and

fitting a supplemental frequency component of the motor control signal as a second pair of the orthogonal pairs if the previous motor speed is classified as low.

25. The method according to claim 21 wherein the step of identifying comprises:

determining a mean squared error between the first orthogonal pairs and the current wave; and

determining reductions in the mean squared error between the orthogonal pairs and the current wave based on the addition of each of the frequency pairs as the subsequent orthogonal pair.

26. A method of estimating a motor speed comprising:

determining a correlation between a current wave sensed at the motor and frequency pairs from a set of weighted frequency pairs representing the current wave;

fitting components of a motor control signal to a corresponding number of first orthogonal pairs in a set of weighted orthogonal pairs, the orthogonal pairs being orthogonal to the frequency pairs;

comparing a subharmonic from the current wave with a harmonics speed model to identify regions in which to locate a corresponding harmonic, the subharmonic having a frequency less than a motor control signal;

identifying a harmonics pair of frequencies in the regions having a separation from each other of no greater than a smallest harmonic of the motor control signal, wherein one of the frequencies is the harmonics pair of the corresponding harmonic; and

comparing the harmonics pair with the harmonics speed model to determine an estimate for the speed.

27. The method according to claim 26 wherein the step of determining a correlation comprises:

calculating a zero-filled fast fourier transform of the current wave using the frequency pairs, wherein the frequency pairs correspond to frequency index bins of the zero-filled fast fourier transform.

28. The method according to claim 26 wherein the step of fitting components of the motor control signal comprises:

determining the orthogonal weights of the first orthogonal pairs based on the values of the components; and

determining the frequency weights of pairs in the set of frequency pairs corresponding to the first orthogonal pairs based on the determined orthogonal weights.

29. The method according to claim 26 wherein the step of fitting components of the motor control signal comprises:

determining if a previous motor speed is classified as low;

fitting a drive frequency component of the motor control signal as a first pair of the orthogonal pairs; and

fitting a supplemental frequency component of the motor control signal as a second pair of the orthogonal pairs if the previous motor speed is classified as low.

30. The method according to claim 26 wherein the step of comparing a subharmonic comprises:

searching the current wave for subharmonics between 0Hz and the frequency of the motor control signal using real-time fast orthogonal searching.

31. The method according to claim 26 wherein the step of identifying a pair of frequencies comprises:

searching for harmonic frequencies of the subharmonics in the regions using real-time fast orthogonal searching;

determining the harmonics pairs from frequencies in the regions that have a separation from each other of no greater than a smallest harmonic of the motor control signal.

32. The method according to claim 26 wherein the step of comparing comprises:

selecting the harmonics pairs having the greatest distance from harmonics of the motor control signal; and

comparing the selected pairs with the motor speed harmonic model to determine an estimate for the speed.

33. A system for estimating a motor speed comprising:

a correlation mechanism for determining a correlation between a current wave sensed at the motor and frequency pairs from a set of weighted frequency pairs representing the current wave;

a fitting mechanism for fitting components of a motor control signal to at corresponding number of first orthogonal pairs in a set of weighted orthogonal pairs and fitting each of the frequency pairs as the orthogonal pair subsequent to the first orthogonal pairs, the orthogonal pairs being orthogonal to the frequency pairs;

an mse reduction mechanism for determining a reduction in the mean squared error between the current wave and the set of weighted orthogonal pairs;

a pair comparison mechanism for identifying the frequency pairs having a reduction that satisfies a criteria;

a speed estimation mechanism for comparing desired frequencies from the identified frequency pairs with a motor speed harmonic model to determine an estimation of the speed; and

a controller in communication with the correlation mechanism, the fitting mechanism, the mse reduction mechanism and the speed estimation mechanism for coordinating the process of estimating the motor speed.

34. The system according to claim 33 further comprising:

an mse mechanism for determining a mean squared error between the current wave and the orthogonal pairs.

35. The system according to claim 33 further comprising:

a harmonics recognition mechanism for removing frequencies that are harmonics of the components of the motor control signal from the identified frequency pairs to form the desired frequencies.

36. The system according to claim 33 wherein the fitting mechanism comprises:

an orthogonal weights mechanism for determining the orthogonal weight for an orthogonal pair from the set of weighted orthogonal pairs based on the value of one of the frequency pairs; and

a frequency weights mechanism for determining the frequency weight for a frequency pair from the set of weighted frequency pairs based on the corresponding orthogonal weight.

37. The system according to claim 33 further comprising:

a CDF analysis mechanism for determining if a previous motor speed is classified as low and providing a supplement frequency component of the motor control signal to the fitting mechanism to be fit as a second pair of the orthogonal pairs if the previous motor speed is classified as low.

38. A system for estimating a motor speed comprising:

a correlation mechanism for determining a correlation between a current wave sensed at the motor and frequency pairs from a set of weighted frequency pairs representing the current wave;

a fitting mechanism for fitting components of a motor control signal to a corresponding number of first orthogonal pairs in a set of weighted orthogonal pairs, the orthogonal pairs being orthogonal to the frequency pairs;

a region determination mechanism for comparing a subharmonic from the current wave with a harmonics speed model to identify two regions in which to locate a corresponding harmonic, the subharmonic having a frequency less than a motor control signal;

a corresponding frequencies mechanism for identifying a harmonics pair of frequencies in the two regions having a separation from each other no greater than a smallest harmonic of the motor control signal, wherein one f the frequencies in the harmonics pair is the corresponding harmonic;

a speed estimation mechanism for comparing desired frequencies from the identified harmonics pairs with a harmonics speed model to determine an estimation of the speed; and

a controller in communication with the correlation mechanism, the fitting mechanism, the mse reduction mechanism and the speed estimation mechanism for coordinating the process of estimating the motor speed.

39. The system according to claim 38 wherein the fitting mechanism comprises:

an orthogonal weights mechanism for determining the orthogonal weight for an orthogonal pair from the set of weighted orthogonal pairs based on the value of one of the frequency pairs; and

a frequency weights mechanism for determining the frequency weight for a frequency pair from the set of weighted frequency pairs based on the corresponding orthogonal weight.

40. The system according to claim 38 further comprising:

a CDF analysis mechanism for determining if a previous motor speed is classified as low and providing a supplement frequency component of the motor control signal to the fitting mechanism to be fit as a second pair of the orthogonal pairs if the previous motor speed is classified as low.

41. The system according to claim 38 further comprising:

a subharmonics mechanism for searching the current wave for subharmonics between 0Hz and the frequency of the motor control signal.

42. The system according to claim 37 further comprising:

a harmonics identification mechanism for locating harmonics in the regions.

43. A computer readable medium having stored thereon computer-executable instructions for estimating a speed of a motor comprising:

a) determining a correlation between a current wave sensed at the motor and frequency pairs from a set of weighted frequency pairs representing the current wave;

b) fitting components of a motor control signal to a corresponding number of first orthogonal pairs in a set of weighted orthogonal pairs, the orthogonal pairs being orthogonal to the frequency pairs;

c) fitting each of the frequency pairs as the orthogonal pair subsequent to the first orthogonal pairs;

d) identifying the frequency that provide a reduction in the mean squared error between the current wave and the set of weighted orthogonal pairs that satisfies a criteria; and

e) comparing desired frequencies from the identified frequency pairs with a motor speed harmonic model to determine an estimation of the speed.

44. A computer readable medium having stored thereon computer-executable instructions for estimating a motor speed comprising:

determining a correlation between a current wave sensed a the motor and frequency pairs from a set of weighted frequency pairs representing the current wave;

fitting components of a motor control signal to a corresponding number of first orthogonal pairs in a set of weighted orthogonal pairs, the orthogonal pairs being orthogonal to the frequency pairs;

comparing a subharmonic from the current wave with a harmonics speed model to identify regions in which to locate a corresponding harmonic, the subharmonic having a frequency less than a motor control signal;

identifying a pair of frequencies in the regions having a separation from each other no greater than a smallest harmonic of the motor control signal, wherein one of the frequencies in the pair is the corresponding harmonic; and

comparing the pair of frequencies with the motor speed harmonic model to determine an estimate for the speed.

45. A computer readable medium having stored thereon computer-executable instructions for estimating a speed of a motor using a current wave sensed at the motor, the method comprising:

determining a correlation between a current wave sensed at the motor and frequency pairs from a set of weighted frequency pairs representing the current wave;

fitting components of a motor control signal to a corresponding number of first orthogonal pairs in a set of weighted orthogonal pairs, the orthogonal pairs being orthogonal to the frequency pairs;

fitting each of the frequency pairs as the orthogonal pair subsequent to the first orthogonal pairs;

determining a reduction for each of the frequency pairs in a mean squared error between the current wave and the set of weighted orthogonal pairs according to a mean squared error between the current wave and the first orthogonal pairs;

determining the reductions that satisfy a criteria and the corresponding frequency pairs;

removing unwanted frequencies from the determined corresponding frequency pairs; and

comparing the remaining frequencies from the determined corresponding frequency pairs with a motor speed harmonic model to determine an estimate for the speed.